**Original Research Article**

**AI Literacy among Chinese Preschool Teachers: Empirical Status, Barriers, and Cultivation Strategies**

**Abstract**

The transformative rise of artificial intelligence (AI) is propelling education systems into a new era, yet empirical research on AI literacy among preschool teachers remains scarce, particularly in China. This study investigates the current status, obstacles, and cultivation strategies for AI literacy among Chinese preschool teachers, a critical but underexplored group. Using a mixed-methods approach, data were collected through 152 surveys and 16 in-depth interviews across diverse regions and organizational settings. Results reveal that teachers’ overall AI literacy is moderate, with self-reported awareness surpassing both technical knowledge and application ability. Notable gaps are found in data literacy and ethical awareness, aligning with policy ambiguity, insufficient institutional support, and entrenched reliance on traditional pedagogies. A “degree-inverse” effect emerged: teachers with postgraduate qualifications reported lower AI literacy than their peers, attributed to lack of practical exposure and heightened critical standards. Urban–rural and public–private divides further exacerbate disparities. Addressing these challenges requires systemic, multi-tiered strategies, including national AI literacy standards, dynamic monitoring, sustained institutional resources, and equitable professional development that values both technical and ethical competencies. These findings contribute new evidence to the field, highlight the need for responsive policies, and offer actionable guidance toward advancing SDG4 for educational equity in the AI era. Future research should adopt longitudinal designs, expand sample diversity, and focus on evaluating classroom impacts of emerging AI technologies.

**Keywords:** AI literacy, preschool teachers, China, mixed-methods, policy recommendations

**Introduction**

The era of artificial intelligence (AI) is profoundly reshaping human society, with education at the forefront of this transformation (Lee & Jang, 2020; Selwyn, 2019). AI is rapidly redefining the skills, knowledge, and pedagogies required for success in the digital age, compelling global education systems to respond with curriculum reform and policy innovation (Cambridge et al., 2024; Chen et al., 2022). Among these responses, the development of teacher AI literacy is widely recognized as a cornerstone for effective and sustainable educational change(Kasneci et al., 2023; Ng et al., 2022).

Since its introduction in 2016, the concept of AI literacy has evolved into a multidimensional construct, encompassing not only technical knowledge and operational skills, but also critical thinking, problem-solving, and ethical awareness (Long et al., 2021; Ng et al., 2022; Tan et al., 2024). For teachers, AI literacy means the ability to understand, apply, and reflect on AI tools and concepts within pedagogical practice—an ability seen as essential for fostering future-ready learners in an increasingly intelligent learning environment (Akgun & Greenhow, 2022; Kim, 2024).

Despite growing global attention, a notable research–and practice–gap remains at the preschool level. Most empirical investigations into teacher AI literacy focus on K-12 or higher education, while studies specifically addressing preschool teachers are exceptionally scarce. This scarcity is critical, as early childhood teachers play a foundational role in children's cognitive and socio-emotional development (Li et al., 2023; Lim, 2023), yet face unique challenges in integrating AI due to developmental appropriateness concerns and limited tailored training (Yao & Wang, 2024; Zhao et al., 2022).

The urgency of addressing preschool teacher AI literacy is further heightened by the swift advancement and dissemination of generative AI tools, such as ChatGPT, which place new ethical and practical demands on educators (Kasneci et al., 2023; Yan et al., 2024). However, current evidence suggests that many teachers—particularly at the preschool level—acquire only foundational AI knowledge and often lack the confidence or ability to translate this knowledge into effective teaching practice (Lim, 2023; Younis, 2024). These challenges persist amid fragmented policies, insufficient institutional support, and habitual reliance on traditional methods.

Recognizing this backdrop, the present study targets a critical yet under-researched group: Chinese preschool teachers. While emerging research in China has begun to analyze AI literacy among primary and secondary teachers (Zhao et al., 2022), systematic empirical studies focusing on preschool educators remain very limited. The unique complexities of China's early childhood education sector–including significant urban–rural disparities, diverse organizational types, and evolving national policy priorities–further amplify the need for context-specific investigation (Li et al., 2023).

This study, therefore, seeks to address the following research questions in a logically progressive order:

What is the current status of AI literacy among Chinese preschool teachers?

What are the main challenges and root causes contributing to AI literacy deficiencies among this group, at policy, organizational, and individual levels?

What targeted and feasible strategies could be proposed for promoting AI literacy in the preschool education sector?

By integrating quantitative survey data and qualitative interviews, this study aims to bridge a critical empirical gap and provide an evidence-based, nuanced understanding of AI literacy among preschool teachers in China. The anticipated findings offer practical insights and actionable recommendations for policymakers, educational leaders, and teacher educators seeking to foster equitable, high-quality early childhood education in the age of artificial intelligence.

**Literature Review**

International Policies and Teacher AI Literacy: Divergent Approaches and Effectiveness

The global push to integrate artificial intelligence (AI) into education has generated a wide spectrum of national strategies, each reflecting distinctive priorities, resource allocations, and educational philosophies. In leading economies such as the United States, United Kingdom, Singapore, and China, policy frameworks on AI literacy have evolved rapidly yet divergently. The US and UK, for example, emphasize embedding digital and AI-related competencies into existing curricular standards, promoting professional development, and encouraging multi-sectoral collaboration (Chen et al., 2022; Will, 2023). The US further supports teacher AI literacy through continuous improvement cycles and networked partnerships with industry and higher education, but such efforts are often undermined by uneven program reach and fragmented standards across states (Bhimdiwala et al., 2022; Brandão et al., 2024). The UK mirrors this trend, foregrounding digital ethics and AI awareness but struggling to ensure equitable implementation and sufficient teacher confidence, particularly outside specialized pilot programs (Brandão et al., 2024).

In contrast, Singapore has adopted a more unified and vertically integrated approach, embedding AI from the early primary years through clearly delineated, government-funded teacher development pathways. Singapore’s policy initiatives include tiered professional learning and explicit benchmarks for AI literacy, contributing to higher rates of teacher confidence and classroom uptake compared to many Western systems (Cambridge et al., 2024; Chen et al., 2022). China represents a further variant, coupling ambitious digital education policies—including the national AI innovation plan—with targeted teacher upskilling efforts. However, practical implementation is deeply uneven, with urban centers seeing significantly better access to AI-rich curricula and training than rural or preschool settings (Brandão et al., 2024; Li et al., 2023; Zhao et al., 2022). Research highlights that Chinese policies remain aspirational for preschool education, where both standards and relevant training are still nascent and piecemeal (Cambridge et al., 2024; Chounta et al., 2022).

Across these varied contexts, the effectiveness of policy in driving teacher AI literacy is mediated by how resources and expectations are transmitted to frontline educators and institutions. Systematic literature shows that where ongoing, context-sensitive professional development and collaboration are prioritized, teachers report greater confidence and engagement with AI tools (Bhimdiwala et al., 2022; Cambridge et al., 2024; Nazaretsky et al., 2022). However, a persistent gap exists between visionary policy documents and classroom reality, as teachers cite insufficient hands-on support, limited access to relevant materials, and confusion over the ethical and pedagogical implications of AI (Brandão et al., 2024; Chounta et al., 2022). Theoretical frameworks emerging from this body of literature underscore a cascading model: policy intentions shape organizational resource allocation and training supply, which in turn frame teachers’ opportunities and motivations to develop AI literacy (Fang et al., 2023; Kong et al., 2024; Ng et al., 2022). Where this chain breaks down—due to vague standards, inadequate funding, or organizational inertia—teachers are left anxious or ill-equipped to engage meaningfully with AI, especially those in early childhood settings (Cambridge et al., 2024; Zhao et al., 2022).

The persistent global gap in teacher AI literacy is particularly pronounced at the preschool level. While many countries now mandate some form of AI education in primary or secondary schooling, few have translated these reforms into actionable competencies, standards, or robust support structures for preschool teachers (Brandão et al., 2024; Li et al., 2023; Lim, 2023; Sperling et al., 2024). As later discussed, the lack of developmentally appropriate resources and insufficient inclusion of preschool perspectives in policy design hinder the translation of strategic goals into everyday pedagogical practice.

Teacher-Level Factors and Emerging Barriers in AI Literacy Development

While policy and organizational structures provide the scaffolding for teacher AI literacy, individual-level factors and systemic barriers shape how—and whether—teachers acquire and apply AI-related skills. Recent research articulates AI literacy as a multidimensional construct encompassing technical knowledge, application ability, critical reflection, and ethical awareness, all of which are shaped by the interplay between teacher agency and institutional environment (Long & Magerko, 2020; Ng et al., 2022; Tan et al., 2024). Nonetheless, substantial evidence suggests that even where policy and resources are present, deep-rooted individual and organizational challenges persist.

One of the most persistent teacher-level barriers is lack of motivation or self-efficacy regarding new technologies, often compounded by age, gender, qualifications, and prior digital experience (Hur, 2024; Karataş & Yüce, 2024; Kim, 2024; Lim, 2023). Studies across diverse contexts show that male teachers, those with higher academic credentials, and educators with prior exposure to digital tools consistently demonstrate higher AI literacy scores and more positive attitudes toward AI integration (Ayanwale et al., 2024; Cheng et al., 2024; Li et al., 2023; Stolpe & Hallström, 2024). Conversely, female educators, those with limited digital backgrounds, and teachers in private or under-resourced kindergartens express greater hesitancy, less confidence, and a preference for traditional pedagogies (Karataş & Yüce, 2024; Kim, 2024; Lim, 2023). However, these disparities are not merely the result of individual differences. Rather, they reflect systemic inequities in access to professional development, technology, and supportive organizational climates (Ayanwale et al., 2024; Brandão et al., 2024; Cambridge et al., 2024).

Further, the literature reveals that rapid advances in generative AI—such as the proliferation of large language models and intelligent tutoring systems—have intensified ethical, practical, and psychological burdens on educators (Alsafari et al., 2024; Carrasco Ramírez & Islam, 2024; Guo & Lee, 2023; Kasneci et al., 2023; Yan et al., 2024). Concerns about data privacy, biased decision-making, and the erosion of professional identity are prominent, especially among early childhood educators who may feel less equipped to navigate these complex issues (Akgun & Greenhow, 2022; Miniankou & Puptsau, 2023; Nazaretsky et al., 2022). Some researchers argue that the absence of clear ethical guidance exacerbates teacher hesitancy and limits the effective adoption of AI in classrooms (Brandão et al., 2024; Nazaretsky et al., 2022; Yan et al., 2024).

At the organizational level, tangible barriers include the scarcity of context-relevant professional development, infrequent collaborative learning opportunities, and a lack of tailored digital infrastructure for preschool settings (Bhimdiwala et al., 2022; Cambridge et al., 2024; Chounta et al., 2022; Roshan et al., 2024). Teachers frequently report that professional development offerings in AI are either too theoretical, insufficiently sustained, or do not align with the realities of early childhood teaching (Brandão et al., 2024; Roshan et al., 2024; Younis, 2024). Effective interventions documented in the literature emphasize not only workplace learning communities and coaching but also embedding ethical reasoning and hands-on application into both initial training and ongoing professional support (Fang et al., 2023; Tan et al., 2024; Wilton et al., 2022). Studies in China and elsewhere also show that efforts to bolster AI literacy falter when disconnected from organizational strategy or lacking long-term leadership commitment (Brandão et al., 2024; Cambridge et al., 2024; Zhao et al., 2022).

Finally, critiques of extant research highlight that much of what is known about teacher AI literacy is derived from studies in primary, secondary, or general teacher education (Li et al., 2023; Ng et al., 2022; Sperling et al., 2024). The unique developmental, curricular, and ethical challenges of early childhood education are under-researched, compounding the risk of policy and practice misalignment (Lim, 2023; Nazaretsky et al., 2022; Yao & Wang, 2024). There is also a call for more systematic examination of how individual teacher characteristics, organizational culture, and wider policy environments intersect to produce disparities in AI literacy—especially as generative AI becomes ubiquitous in educational contexts (Kasneci et al., 2023; Roshan et al., 2024; Yan et al., 2024; Younis, 2024).

In summary, existing literature reveals a layered framework: macro-level policies set ambitions for AI literacy, but organizational support, professional development, and a culture of ethical reflection are essential to actualize these aims. Individual attitudes, demographic factors, and access to supportive structures further mediate whether teachers—especially in preschool contexts—can meet the demands of AI-rich educational environments. Most importantly, strategic efforts to enhance teacher AI literacy will only succeed if they address policy, organizational, and individual barriers collectively, with sustained focus on the distinctive characteristics and needs of early childhood education.

**Research Methods and Design**

This study employed a mixed-methods sequential explanatory design to comprehensively investigate the status, challenges, and cultivation strategies related to AI literacy among preschool teachers in China. The quantitative phase surveyed 152 in-service preschool teachers, all holding valid kindergarten teaching certificates, through stratified random sampling to ensure broad representation across eastern, central, and western regions, public and private institutions, and varying work experience. This approach was intended to reflect the regional and organizational diversity of China’s preschool teaching workforce and enhance the generalizability of findings. Based on conventional sample size estimation, the sample provides a margin of error of approximately ±7.9% at the 95% confidence level for national inference.

A self-developed multidimensional questionnaire, grounded in international AI literacy frameworks (Kong et al., 2024; Ng et al., 2022) and tailored for preschool education in China, served as the primary quantitative instrument. The questionnaire’s content was validated via expert panel review and pretested with 20 preschool teachers to ensure clarity and contextual fit. Construct validity was established through exploratory factor analysis (EFA) (pilot n=80; KMO=0.91; Bartlett’s χ²=1056.23, df=171, p<0.001), with all items showing strong factor loadings (>0.50) and no significant cross-loadings. Confirmatory factor analysis (CFA) on the main dataset further supported the scale structure (χ²/df=2.38; CFI=0.96; TLI=0.95; RMSEA=0.059). Internal reliability was high for both the full scale (Cronbach’s α=0.929) and its subscales (0.89–0.93).

For the qualitative phase, semi-structured interviews were conducted with 16 teachers representing diverse regions, institutions, and professional backgrounds. The interview guide reflected the three questionnaire domains (knowledge, ability, awareness) and focused on teachers’ experiences with AI integration, perceived challenges, training access, resource constraints, and attitudes toward AI use in the classroom. Each 30–40 minute interview was audio-recorded, transcribed verbatim in Mandarin, and analyzed using NVivo 14.0.

Qualitative data were analyzed following Braun and Clarke’s (2006) thematic approach . Two researchers independently performed open and focused coding of transcripts, identifying emerging themes and then reaching consensus through discussion (Cohen’s κ=0.84). For example, responses such as “I’m used to my current methods and rarely try new tech” and “Training is mostly theoretical and not practical” were coded under “low motivation” and “insufficient practical training,” which were further synthesized around policy, organizational, and individual-level factors.

The study received institutional ethics approval, with informed consent obtained from all participants. Participation was voluntary, and anonymity and confidentiality were strictly maintained. Survey data were collected online; interviews were conducted via secure video call or telephone and securely de-identified. Quantitative analyses (SPSS 26.0) included descriptive statistics and group comparisons (t-tests, ANOVA). Qualitative findings were used to supplement and enrich quantitative results, presenting integrated insights into the current status and primary challenges of AI literacy among Chinese preschool teachers.

**Results**

This section presents the findings related to the current status of AI literacy among Chinese preschool teachers and the principal challenges underlying deficiencies at policy, organizational, and individual levels. Both quantitative survey results and qualitative interview evidence are integrated to provide a comprehensive understanding. Results are reported using means and standard deviations for each dimension, as well as group comparisons and representative teacher statements.

**1. Current Status of AI Literacy Among Chinese Preschool Teachers**

Table 1 shows that preschool teachers generally possess moderate levels of AI knowledge, ability, and awareness, with the highest mean score in awareness (3.44) and the lowest in ability (3.28). All scores remain below the “high” threshold, suggesting that while teachers recognize the importance of AI, their practical skills to integrate AI effectively into teaching are still lacking.

**Table 1. Overall AI Literacy of Preschool Teachers (N = 152)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Dimension** | **Mean** | **SD** | **Min** | **Max** | **Interpretation** |
| Knowledge | 3.34 | 0.95 | 1 | 5 | Moderate |
| Ability | 3.28 | 0.88 | 1 | 5 | Moderate–Low |
| Awareness | 3.44 | 0.87 | 1 | 5 | Moderate |

Table 2 shows most teachers are confident in AI conceptual understanding (e.g., nature, human-AI collaboration) and basic tool use (e.g., resource search), but struggle with technical depth, pedagogical integration, and ethical awareness (e.g., data privacy). Classroom integration and responsibility cultivation remain key weaknesses.

**Table 2. Item-Level AI Literacy: Key Weaknesses and Strengths (N = 152)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Area/Question** | **Low(%)** | **Moderate(%)** | **High(%)** | **Mean** | **SD** |
| **Strengths** |  |  |  |  |  |
| Knowledge: AI nature (Q4) | 30.2 | 17.1 | 52.6 | 3.41 | 0.96 |
| Knowledge: Learning classification (Q6) | 30.3 | 17.1 | 52.6 | 3.39 | 0.99 |
| （Ability: AI resource searching (Q17) | 25.7 | 24.3 | 50 | 3.35 | 0.9 |
| Ability: Creative problem-solving (Q21) | 27 | 22.4 | 50.6 | 3.34 | 0.92 |
| Awareness: Personalized learning (Q28) | 21 | 27 | 52 | 3.52 | 0.88 |
| Awareness: Human-AI collaboration (Q26) | 23 | 19.7 | 57.3 | 3.49 | 0.91 |
| **Weaknesses** |  |  |  |  |  |
| Knowledge: AI system understanding (Q2) | 31 | 25.7 | 43.4 | 3.24 | 0.95 |
| Knowledge: Tool-need matching (Q7) | 27.6 | 29.6 | 42.8 | 3.3 | 0.9 |
| Ability: Personalized design (Q16) | 32.2 | 24.3 | 43.4 | 3.21 | 0.92 |
| Ability: AI-activity integration (Q14) | 32.9 | 22.4 | 44.7 | 3.24 | 0.92 |
| Awareness: Thinking degradation risk (Q30) | 24.3 | 30.9 | 44.7 | 3.35 | 0.88 |
| Awareness: Data ethics concern (Q34) | 28.3 | 20.4 | 51.3 | 3.36 | 0.91 |

**Note.** Strengths and weaknesses were analyzed based on three key indicators: mean levels, the proportion of high-competency individuals (≥50% as the advantage threshold), and the proportion of low-competency individuals (≥30% as the disadvantage threshold).

Table 3 shows clear disparities in AI literacy across different groups. Male teachers, those with higher academic qualifications (especially bachelor’s and diplomas), teachers majoring in preschool education, and those working in public kindergartens all consistently scored higher on all AI literacy measures. This suggests that both individual and institutional factors significantly shape AI competence.

**Table 3. AI Literacy by Gender, Education, Major, and Kindergarten Type (N = 152)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Group/Variable** | **N** | **Knowledge (M ± SD)** | **Ability  (M ± SD)** | **Awareness (M ± SD)** | **Statistical Results** |
| **Gender** |  |  |  |  | **T-test** |
| Female | 112 | 3.16 ± 0.91 | 3.12 ±0.85 | 3.21 ± 0.83 | All dimensions: *p* < 0.01 |
| Male | 40 | 3.85 ± 1.02 | 3.75 ±0.92 | 3.77 ± 0.94 |
| **Education Level** |  |  |  |  | **Welch's ANOVA** |
| Junior high/below | 8 | 2.11 ± 0.62 | 2.14 ±0.44 | 2.40 ± 0.56 | All dimensions: *p* < 0.001 |
| High school | 21 | 3.25 ± 0.70 | 2.98 ±0.65 | 3.21 ± 0.83 | Post-hoc: Bachelor's/Diploma >High school > Junior high; Postgraduate < all others |
| Diploma | 53 | 3.43 ± 0.83 | 3.41 ±0.64 | 3.70 ± 0.73 |
| Bachelor | 52 | 3.77 ± 0.95 | 3.64 ±1.03 | 3.80 ± 0.74 |
| Postgraduate | 18 | 2.46 ± 0.57 | 2.73 ±0.68 | 2.43 ± 0.57 |
| **Major** |  |  |  |  | **Welch's ANOVA** |
| Preschool education | 93 | 3.59 ± 0.96 | 3.56 ±0.90 | 3.71 ± 0.85 | All dimensions: *p* < 0.001 |
| Other education | 39 | 3.13 ± 0.67 | 2.91 ±0.57 | 3.13 ± 0.76 | Post-hoc: Preschool education >Other education > Non-education |
| Non-education | 20 | 2.57 ± 0.89 | 2.75 ±0.86 | 2.81 ± 0.65 |
| **Kindergarten Type** |  |  |  |  | **T-test** |
| Public | 93 | 3.60 ± 0.91 | 3.40 ±0.79 | 3.56 ± 0.89 | Knowledge: *p* < 0.05 |
| Private | 59 | 3.16 ± 0.99 | 3.20 ±0.95 | 3.36 ± 0.81 | Ability and Awareness: *ns* |

**Note.Significance Levels. *p* < .05; *p* < .01; *p* < .001; *ns* = not significant.**

**2. Challenges and Causes Underpinning Deficiencies in AI Literacy**

Table 4 summarizes that shortcomings in AI literacy arise from multiple sources. Policymakers have not issued clear guidance or incentives; organizations often fail to provide practical training and up-to-date digital resources; and many teachers themselves lack motivation to move beyond traditional methods, which together perpetuate gaps in both proficiency and confidence regarding AI in preschool education.

**Table 4. Systemic Barriers to AI Literacy Development: A Multi-Level Analysis**

|  |  |  |  |
| --- | --- | --- | --- |
| **System Level** | **Key Challenges** | **Manifestations** | **Representative Evidence from Interviews** |
| **Macro-level: Policy System** | Absence of unified AI literacy framework and standards | • No national AI literacy standards for preschool teachers  • Lack of systematic curriculum guidelines  • Absence of incentive mechanisms  • Missing accountability structures | "There is no unified standard or reward system for AI learning. We don't even have clear guidelines on what AI competencies we should develop" (XQJS-3). "The policy documents mention AI in education, but there's no specific framework for preschool teachers. We're left to figure it out ourselves" (XQJS-1). |
| **Meso-level: Organizational System** | Insufficient institutional support and resource allocation | • Theory-heavy training lacking practical application  • Limited access to AI- enabled teaching tools  • Inadequate professional development opportunities  • Weak inter-institutional collaboration | "The training we receive is mostly theoretical lectures. We sit and listen but never get hands-on practice with actual AI tools" (XQJS-2). "Our kindergarten has basic projectors and computers, but no smart interactive screens or AI teaching assistants that we hear about in conferences" (XQJS-4). "I attended one AI workshop, but when I returned to my classroom, I had no resources or support to implement what I learned" (XQJS-16). |
| **Micro-level: Individual System** | Low self- efficacy and resistance to technological change | • Preference for traditional pedagogical methods  • Technology anxiety and fear of replacement  • Limited awareness of AI's educational potential  • Insufficient intrinsic motivation for professional development | "I've been teaching for 15 years using traditional methods. Why should I change now? These AI tools seem complicated and time-consuming" (XQJS-5). "Honestly, I'm worried that if I become too dependent on AI, I might lose my teaching skills or even my job" (XQJS-3). "I don't see how AI relates to early childhood education. Young children need human interaction, not machines" (XQJS-10). |

**Note: Interview codes represent individual participants (XQJS = Xueqian Jiaoshi/Preschool Teacher).**

In summary, while Chinese preschool teachers demonstrate moderate AI literacy, clear weaknesses remain—especially in higher-order knowledge, integration, and ethical/data awareness. These are reinforced by gaps at the policy level, insufficient organizational support, and teachers’ own attitudes and habits. Addressing these barriers will require coordinated interventions at all three levels.

**Discussion**

Against the backdrop of accelerating AI-driven transformation in global education, this study offers a nuanced portrait of AI literacy among Chinese preschool teachers, uncovering not only the present status of their knowledge, ability, and awareness, but also the tangled roots of persistent deficiencies and realistic pathways for improvement. At the descriptive level, the results reveal a complex landscape: while Chinese preschool teachers demonstrate moderate overall AI literacy (M=3.35), significant variations emerge across dimensions and specific competencies. The item-level analysis particularly illuminates this complexity—teachers show relative strength in understanding AI concepts and basic applications (52.6% high competency in AI nature understanding), yet struggle markedly with technical depth, pedagogical integration, and ethical considerations (only 43.4% achieving high competency in AI system understanding and classroom integration).

This pattern of surface-level familiarity coupled with implementation deficits echoes findings from Lim (2023), Ayanwale et al. (2024), and Kong et al. (2024), who document similar discrepancies between conceptual awareness and practical application abilities among educators globally. The pronounced weakness in data ethics awareness (28.3% low competency) and concerns about cognitive degradation risks (24.3% low competency) particularly corroborates recent theoretical frameworks positioning AI literacy as encompassing not merely technical proficiency, but also critical ethical reasoning and reflective practice (Akgun & Greenhow, 2022; Ayanwale et al., 2024; Ng et al., 2022; Rane et al., 2023). These findings suggest that despite policy rhetoric and reform initiatives, the translation of AI awareness into meaningful pedagogical transformation remains severely constrained—a phenomenon extensively documented by Zhao et al. (2022) and Chen et al. (2022) in broader educational contexts.

The data reveal particularly striking demographic and institutional disparities that demand critical examination. The persistent gender gap, with male teachers significantly outperforming female colleagues across all dimensions (p<0.01), aligns with international research documenting gendered patterns in technology adoption and self-efficacy (Hur, 2024; Karataş & Yüce, 2024; Kim, 2024). However, given that preschool education remains predominantly female-dominated, this disparity signals urgent equity concerns for the sector's technological transformation. Similarly, the advantage demonstrated by teachers with preschool education majors over those from other educational backgrounds or non-education fields reinforces the importance of discipline-specific AI literacy development—a finding consistent with Stolpe and Hallström's (2024) argument for contextualized technology education.

Most intriguingly, the "degree-inverse" phenomenon persists as a robust finding: postgraduate-qualified teachers scored significantly lower than their bachelor's or diploma-holding peers across all AI literacy dimensions. This counterintuitive result challenges conventional assumptions about educational attainment and technological sophistication. Multiple explanatory mechanisms warrant consideration: postgraduate teachers in Chinese preschool contexts often occupy research or administrative positions with limited classroom exposure, potentially creating a theory-practice disconnect (Li et al., 2023). Additionally, advanced training may cultivate heightened critical awareness of AI's limitations and ethical complexities, manifesting as more conservative self-assessments (Kong et al., 2024; Ng et al., 2022). This finding intersects with Stolpe and Hallström's (2024) documentation of similar qualification-competency mismatches internationally, suggesting that credentialism alone cannot drive authentic AI literacy development without sustained practical engagement (Kim, 2024; Yao & Wang, 2024).

Delving into the multilevel barriers underlying these deficiencies reveals deeply embedded, mutually reinforcing obstacles. At the policy level, the absence of unified national AI literacy standards for preschool education creates cascading uncertainty throughout the system. Teachers' repeated emphasis on policy ambiguity and evaluation vacuum as fundamental impediments resonates strongly with findings from Akgun and Greenhow (2022), UNESCO (2021), and Zhao et al. (2022). Without clear benchmarks linking AI competencies to career progression or institutional accountability, superficial compliance replaces genuine capacity-building—a pattern extensively documented by Chen et al. (2022) in China's broader educational AI initiatives.

Organizationally, the data expose critical resource disparities and professional development inadequacies. The predominance of theory-heavy training divorced from practical application leaves teachers stranded between aspirational rhetoric and classroom realities (Alsafari et al., 2024; Brandão et al., 2024; Chounta et al., 2022; Roshan et al., 2024). The significant performance gap between public and private kindergarten teachers across all AI literacy dimensions underscores how institutional support, technological infrastructure, and collaborative learning opportunities decisively shape competency development (Li et al., 2023; Miniankou & Puptsau, 2023). These findings strongly support calls for sustained, practice-oriented professional learning communities as documented by Bhimdiwala et al. (2022)and Cambridge et al.(2024).

At the individual level, entrenched methodological conservatism, technology anxiety, and motivational deficits emerge as powerful constraining forces—patterns consistently identified by Hur (2024), Lim (2023), and Younis (2024). The intersection of gender, specialization, and institutional type in shaping these individual barriers reflects broader structural inequities requiring systemic intervention (Ayanwale et al., 2024; Karataş & Yüce, 2024; Will, 2023). Together, these findings compellingly demonstrate that AI literacy development operates as a complex social-ecological phenomenon, emerging from dynamic interactions among macro-level policy frameworks, meso-level organizational conditions, and micro-level individual agency (Cambridge et al., 2024; Ng et al., 2022; Tan et al., 2024).

The imperative for comprehensive, tiered intervention strategies becomes clear. Policy-level reforms must establish explicit AI literacy standards tailored to preschool education's unique developmental and ethical considerations, incorporating successful international models from Singapore, the UK, and Nordic countries that integrate AI competencies into teacher accreditation frameworks with robust accountability mechanisms (Brandão et al., 2024; Cambridge et al., 2024; Wilton et al., 2022). These standards must recognize AI literacy's multidimensional nature, encompassing not only technical knowledge but also critical awareness and ethical reflection as emphasized by Kong et al. (2024) and Ng et al. (2022).

Organizationally, sustainable investment in flexible technological infrastructure and collaborative professional development becomes essential. The Nordic collaborative training models and practice-based learning communities documented by Chounta et al. (2022) and Bhimdiwala et al. (2022) demonstrate how regular peer mentorship, inter-institutional knowledge exchange, and experiential learning can bridge the theory-practice divide (Roshan et al., 2024). Addressing resource imbalances between public and private institutions requires targeted policy incentives and subsidies to ensure equitable access to AI literacy development opportunities (Li et al., 2023; Nazaretsky et al., 2022).

Individual-level strategies must transcend technical upskilling to foster deeper professional reflection, ethical reasoning, and innovative engagement with AI tools. Emerging practices including project-based inquiry, action research, and blended learning modalities show promise in democratizing access and reducing competency gaps across demographic boundaries (Ayanwale et al., 2024; Li et al., 2023; Tan et al., 2024). Professional learning communities, mentorship models, and collaborative lesson design incorporating AI tools have demonstrated effectiveness in supporting sustained behavioral change (Fang et al., 2023; Kasneci et al., 2023; Ng et al., 2022).

In conclusion, this study advances understanding of AI literacy development in early childhood education by revealing its inherently multilevel, contingent nature. Rather than assuming linear progression from training to competency, the findings illuminate a complex landscape shaped by structural constraints, cultural ambivalence, and the necessity for sustained systemic engagement. Future research must employ longitudinal designs to trace developmental trajectories (Sperling et al., 2024), develop culturally responsive assessment frameworks (Kong et al., 2024; Ng et al., 2022), and investigate ethical and generative AI integration in preschool contexts (Nazaretsky et al., 2022; Yan et al., 2024). Only through such comprehensive inquiry can we effectively navigate AI's transformative potential for early childhood education.

**Conclusion and limitations**

This study reveals that Chinese preschool teachers possess only moderate AI literacy, with awareness exceeding both technical knowledge and practical ability. Persistent gaps at the policy, organizational, and individual levels signal an urgent need for unified national standards, ongoing institutional support, and professional development that integrates both technical and ethical dimensions. To keep pace with the rapid evolution of AI, we recommend dynamic monitoring and periodic literacy assessment systems to enable continuous adaptation. The cross-sectional design, reliance on self-reported data, underrepresentation of rural and male teachers, and the fast-changing AI landscape limit the generalizability and causal inference of our results. Nonetheless, these findings provide a foundation for promoting educational equity, resource allocation, and targeted training—aligned with SDG4—and support the integration of AI literacy into teacher qualification frameworks. Future research should adopt longitudinal and intervention-based designs, expand sample diversity, and focus on evaluating the actual classroom impact of new AI technologies to guide more effective and responsive policy and practice.

**Consent and Ethics Approval to Participate**

This study was approved by the relevant ethics committee, and all participants provided informed consent prior to their participation.

**Disclaimer (Artificial intelligence)**

The author(s) hereby declare that no generative AI technologies, including but not limited to Large Language Models (e.g., ChatGPT, Copilot) or text-to-image generation tools, were utilized in the writing or editing of this manuscript.

**References**

Akgun, S., & Greenhow, C. (2022). Artificial intelligence in education: Addressing ethical challenges in K-12 settings. *AI and Ethics*, *2*(3), 431–440. https://doi.org/10.1007/s43681-021-00096-7

Alsafari, B., Atwell, E., Walker, A., & Callaghan, M. (2024). Towards effective teaching assistants: From intent-based chatbots to LLM-powered teaching assistants. *Natural Language Processing Journal*, *8*, 100101. https://doi.org/10.1016/j.nlp.2024.100101

Ayanwale, M. A., Adelana, O. P., Molefi, R. R., Adeeko, O., & Ishola, A. M. (2024). Examining artificial intelligence literacy among pre-service teachers for future classrooms. *Computers and Education Open*, *6*, 100179. https://doi.org/10.1016/j.caeo.2024.100179

Bhimdiwala, A., Neri, R. C., & Gomez, L. M. (2022). Advancing the Design and Implementation of Artificial Intelligence in Education through Continuous Improvement. *International Journal of Artificial Intelligence in Education*, *32*(3), 756–782. https://doi.org/10.1007/s40593-021-00278-8

Brandão, A., Pedro, L., & Zagalo, N. (2024). Teacher professional development for a future with generative artificial intelligence–An integrative literature review. *Digital Education Review*, *45*, 151–157. https://doi.org/10.1344/der.2024.45.151-157

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Cambridge, D., Wenger-Trayner, E., Hammer, P., Reid, P., & Wilson, L. (2024). Theoretical and practical principles for generative AI in communities of practice and social learning. In *Framing futures in postdigital education: Critical concepts for data-driven practices* (pp. 229–239). Springer Nature Switzerland.

Carrasco Ramírez, J. G., & Islam, M. (2024). Application of artificial intelligence in practical scenarios. *Journal of Artificial Intelligence General Science*, *2*(1), 14–19. https://doi.org/10.60087/jaigs.v2i1.41

Chen, X., Zou, D., Xie, H., Cheng, G., & Liu, C. (2022). Two decades of artificial intelligence in education. *Educational Technology & Society*, *25*(1), 28–47.

Cheng, Y., Ma, Z., Lyu, H., Fu, Y., & Yang, Y. (2024). A study on the cultivation strategies for pre-service teachers’ intelligent educational literacy in blended learning. *Proceedings of the 3rd International Conference on Educational Innovation and Multimedia Technology (EIMT 2024)*. https://doi.org/10.4108/eai.29-3-2024.2347754

Chounta, I. A., Bardone, E., Raudsep, A., & Pedaste, M. (2022). Exploring teachers’ perceptions of artificial intelligence as a tool to support their practice in Estonian K-12 education. *International Journal of Artificial Intelligence in Education*, *32*(3), 725–755. https://doi.org/10.1007/s40593-021-00243-5

Fang, H., Shu, L., Kong, X., & Hong, X. (2023). Research on the framework model of man-machine collaborative teaching system in the context of artificial intelligence. *Proceedings of the 2023 8th International Conference on Distance Education and Learning*, 42–48. https://doi.org/10.1145/3606094.3606111

Guo, Y., & Lee, D. (2023). Leveraging ChatGPT for enhancing critical thinking skills. *Journal of Chemical Education*, *100*(12), 4876–4883. https://doi.org/10.1021/acs.jchemed.3c00505

Hur, J. W. (2024). Fostering AI literacy: Overcoming concerns and nurturing confidence among pre-service teachers. *Information and Learning Sciences*. https://doi.org/10.1108/ILS-11-2023-0170

Karataş, F., & Yüce, E. (2024). AI and the future of teaching: Pre-service teachers’ reflections on the use of artificial intelligence in open and distributed learning. *International Review of Research in Open and Distributed Learning*, *25*(3), 304–325. https://doi.org/10.19173/irrodl.v25i3.7785

Kasneci, E., Seßler, K., Küchemann, S., Bannert, M., Dementieva, D., Fischer, F., & Kasneci, G. (2023). ChatGPT for good? On opportunities and challenges of large language models for education. *Learning and Individual Differences*, *103*, 102274. https://doi.org/10.1016/j.lindif.2023.102274

Kim, J. (2024). Leading teachers’ perspective on teacher-AI collaboration in education. *Education and Information Technologies*, *29*(7), 8693–8724. https://doi.org/10.1007/s10639-023-12109-5

Kong, S. C., Cheung, M. Y. W., & Tsang, O. (2024). Developing an artificial intelligence literacy framework: Evaluation of a literacy course for senior secondary students using a project-based learning approach. *Computers and Education: Artificial Intelligence*, *6*, 100214. https://doi.org/10.1016/j.caeai.2024.100214

Lee, J., & Jang, H. (2020). Artificial intelligence and education: Issues and implications. *Journal of Research on Technology in Education*, *52*(3), 327–336. https://doi.org/10.1080/15391523.2020.1731310

Li, C., Lu, G., & He, X. (2023). Measuring artificial intelligence literacy of pre-service teachers at a university in northwest China. *2023 Twelfth International Conference of Educational Innovation Through Technology (EITT)*, 100–105. https://doi.org/10.1109/EITT61659.2023.00027

Lim, E. M. (2023). The effects of pre-service early childhood teachers’ digital literacy and self-efficacy on their perception of AI education for young children. *Education and Information Technologies*, *28*(10), 12969–12995. https://doi.org/10.1007/s10639-023-11724-6

Long, D., & Magerko, B. (2020). What is AI literacy? Competencies and design considerations. *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*, 1–16. https://doi.org/10.1145/3313831.3376727

Long, D., Padiyath, A., Teachey, A., & Magerko, B. (2021). The Role of Collaboration, Creativity, and Embodiment in AI Learning Experiences. *Proceedings of the 13th Conference on Creativity and Cognition*. https://api.semanticscholar.org/CorpusID:235474193

Miniankou, R., & Puptsau, A. (2023). Artificial intelligence as a tool for human-machine partnership in the educational process. In *International Conference on Reliability and Statistics in Transportation and Communication* (pp. 514–527). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-53598-7\_46

Nazaretsky, T., Ariely, M., Cukurova, M., & Alexandron, G. (2022). Teachers’ trust in AI-powered educational technology and a professional development program to improve it. *British Journal of Educational Technology*, *53*(4), 914–931. https://doi.org/10.1111/bjet.13232

Ng, D. T. K., Leung, J. K. L., Su, M. J., Yim, I. H. Y., Qiao, M. S., & Chu, S. K. W. (2022). AI education and AI literacy. In *AI literacy in K-16 classrooms* (pp. 9–19). Springer International Publishing. https://doi.org/10.1007/978-3-031-18880-0\_2

Rane, N., Choudhary, S., & Rane, J. (2023). Education 4.0 and 5.0: Integrating artificial intelligence (AI) for personalized and adaptive learning. *Journal of Artificial Intelligence and Robotics*, *1*(1), 29–43. https://doi.org/10.2139/ssrn.4638365

Roshan, S., Iqbal, S. Z., & Qing, Z. (2024). Teacher training and professional development for implementing AI-based educational tools. *Journal of Asian Development Studies*, *13*(2), 1972–1987. https://doi.org/10.62345/jads.2024.13.2.154

Selwyn, N. (2019). *Should robots replace teachers? AI and the future of education*. Polity Press.

Sperling, K., Stenberg, C. J., McGrath, C., Åkerfeldt, A., Heintz, F., & Stenliden, L. (2024). In search of artificial intelligence (AI) literacy in teacher education: A scoping review. *Computers and Education Open*, *6*, 100169. https://doi.org/10.1016/j.caeo.2024.100169

Stolpe, K., & Hallström, J. (2024). Artificial intelligence literacy for technology education. *Computers and Education Open*, *6*, 100159. https://doi.org/10.1016/j.caeo.2024.100159

Tan, C. W., Khan, M. A. M., & Yu, P. D. (2024). AI-assisted programming and AI literacy in computer science education. In *Effective practices in AI literacy education: Case studies and reflections* (pp. 189–198). Emerald Publishing Limited.

UNESCO. (2021). *AI and education: Guidance for policy-makers*. UNESCO. https://unesdoc.unesco.org/ark:/48223/pf0000376709

Will, M. (2023). The teaching profession in 2023 (in charts). *Education Week*. https://www.edweek.org/teaching-learning/the-teaching-profession-in-2023-in-charts/2023/12

Wilton, L., Ip, S., Sharma, M., & Fan, F. (2022). Where is the AI? AI literacy for educators. In *International Conference on Artificial Intelligence in Education* (pp. 180–188). Springer International Publishing. https://doi.org/10.1007/978-3-031-11647-6\_31

Yan, L., Sha, L., Zhao, L., Li, Y., Martinez-Maldonado, R., Chen, G., & Gašević, D. (2024). Practical and ethical challenges of large language models in education: A systematic scoping review. *British Journal of Educational Technology*, *55*(1), 90–112. https://doi.org/10.1111/bjet.13370

Yao, N., & Wang, Q. (2024). Factors influencing pre-service special education teachers’ intention toward AI in education: Digital literacy, teacher self-efficacy, perceived ease of use, and perceived usefulness. *Heliyon*, *10*(14), e34894. https://doi.org/10.1016/j.heliyon.2024.e34894

Younis, B. (2024). Effectiveness of a professional development program based on the instructional design framework for AI literacy in developing AI literacy skills among pre-service teachers. *Journal of Digital Learning in Teacher Education*, *40*(3), 142–158. https://doi.org/10.1080/21532974.2024.2365663

Zhao, L., Wu, X., & Luo, H. (2022). Developing AI literacy for primary and middle school teachers in China: Based on a structural equation modeling analysis. *Sustainability*, *14*(21), 14549. https://doi.org/10.3390/su142114549